Flashjet® Mobile Manipulator Development Project

Project Sponsor: CNO N45
Project Lead: NAVAIR Depot Jacksonville
Prime Contractor: Flash Tech, Inc.
Robot Sub-Contractor: PaR Systems, Inc.

Phase III Demonstration Final Report

July 14th, 2003

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Process Engineering Branch
Code 6.3.1.4

Mobile Fashjet® Phase III Demonstration Report

Table of Contents

Tables: ***(Supporting Data Tables Available Upon Request)***

1.0 Executive Summary:

This report identifies project goals and objectives and summarizes the results as well as recommendations of the Mobile Flashjet® Development Project. The project was structured in four (4) phases to provide a systematic approach for the manipulator development while minimizing investment risk and providing program management approval/concurrence of the results of each phase prior to contracting for the next phase. In general, this project's statement of work required the development of a mobile flashjet® system that would be capable of removing the surface coating from 90% of the outer mold-line of a P-3 Orion aircraft within 120 hours. This goal was derived based upon maintaining a workload of 30 aircraft per year and meeting throughput times of chemical stripping operations. In addition this goal is based on a two shift flashjet® operation with a requirement for one system. The four phases of the project are described as follows:

> *Phase I* - 3 D Simulate/Design/Build/Demo the Mobile Manipulator (Phase I effort completed August 7th, 2001)
>
> *Phase II* – Demonstrate Mobile Manipulator Reach & Maximum P-3 Paint Strip Potential/Generate Process Time & Cost Models (Phase II effort completed October 2001)
>
> *Phase III* – Perform Live Paint Strip Technology Demonstrations/Validate Maximum Strip Potential, Process Time & Cost Models
>
> *Phase IV* – Make Investment Decision/Acquire Funding/Procure Mobile FJ System

Phase III Demonstrations completed April 1st, 2003 and the contractor provided a final report to the depot May 28th, 2003. Phase III utilized the contractor owned Mobile Manipulator, rented equipment and government procured equipment to make up a complete FLASHJET® Coatings Removal System. The primary objective of Phase III was to demonstrate levels of FLASHJET System and Manipulator performance to validate the findings of Phase I and Phase II, and to provide data that supports justification to proceed with Phase IV and system procurement.

In general, Phase III results show that strip time projection is approximately 104 hours which is well within the established goal of 120 hours. However, the amount of paint strip continues to track well below the target strip of 90% and is projected to be less than 85% for most P-3 aircraft. This continues to be a major shortcoming of the flashjet® process and reinforces the need for the contractor to develop a complete paint strip solution that includes the 15 % that cannot be stripped by flashjet®. To their credit, the contractor has proposed integrating a very promising laser strip technology with the mobile flashjet® system. However, this technology is not proven nor commercially available at this time.

During Phase III demonstration Materials and Process Engineering personnel performed a technical review of the flashjet® process and paint strip results. (See Results section of this report.) During this review several secondary process deficiencies were noted. Significant among them were the thermal degradation of conversion coat by flashjet® in areas of in service corrosion repair and the decreased ability to inspect for corrosion damage due to non-uniform appearance of the post flashjet® stripped surface. As a result of these findings and the impact of these findings on downstream processes which determined that process time and cost would be significantly increased, it is not recommended that the depot proceed with procurement of a mobile flashjet® system (Phase IV). Instead, it is recommended that the depot expedite installation of new PMB booth for aircraft (that will immediately reduce PMB consumption and waste streams) and vigorously pursue proposed upgrades to water treatment plant #2 that should dramatically reduce hazardous material use and waste streams generated from chemical strip operations. (See Recommendations of this report.)

Although Flashjet® is not recommended for aircraft paint strip operations, based on the demonstration strip of the P-3 tail radome (stinger) it is recommended that the flashjet® process or other thermal method such as laser strip be pursued as an alternative for stripping composite surfaces such as the P-3 and EA-6B radomes, P-3 tail radome and other large composite aircraft surfaces. Additionally, the flashjet® process is specifically recommended for epoxy and polyester reinforced plastic (composite) surfaces which exhibit difficulty and/or damage with existing chemical, PMB, or hand sanding process methods. In these instances the flashjet® process can provide improved product quality and performance at potentially reduced cost. It is further recommended that such a facility be designed similar to the radome facility at Warner Robins AFB with capability to handle all radome work for the Navy. (See Recommendations section of this report.)

Finally, while our current aircraft strip processes are compliant, it is vital that the Navy continue to seek alternative paint strip solutions to ensure continued aircraft paint strip operations capability as ESH drivers continue to become ever more restrictive.

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P-3 FST Leader: Mr. Bob Livingston & Mr. Bruce Keen
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2.0 Background Information:

2.1 Requirement/Policy Drivers: In the paint removal industry, in addition to seeking a safer working environment for personnel, elimination of hazardous materials and hazardous waste streams is the goal of the Clean Air and Clean Water Acts, the Resource Conservation and Recovery Act (RCRA) and the National Emission Standards for Hazardous Air Pollutants (NESHAPS).

2.2 Problem Statement: During the life cycle of military aircraft, paint stripping and recoating are required periodically for inspection, maintenance, and repair as well as for changes in paint schemes and special purpose coatings. Two predominate methods to strip aircraft continue to be Plastic Media Blast (PMB) and non-hazardous air pollutant (Non-HAP) chemical stripping. Currently, Depot Jacksonville uses a benzyl alcohol activated, Non-HAP product to perform paint stripping of P-3 aircraft and Plastic Media Blast (PMB) to remove paint from fighter sized aircraft including EA-6B, F-14, S-3, F-18 and H-60. Both processes are supplemented by hand sanding (10-20%) to strip areas not accessible by either chemical or PMB strip methods. Both methods require use of hazardous materials, produce large waste streams and require a significant amount of personnel protective equipment (PPE) and personnel exposure monitoring by OSH Office. Additionally, intrusion of chemicals and PMB into aircraft is a potential source of concern. (Refer to LMTCE NAS #103 & #107 at www.enviro-navair.navy.mil)

2.3 Proposed Solution: In an effort to find a more environmentally acceptable and safer alternative to chemical and abrasive blast strip methods, the Navy and the Air Force together with the Boeing Company developed the Flashjet ® process. In 1998, NAVAIRSYSCOM authorized Flashjet® use on metallic fixed-wing aircraft structures. In 1999, NAWCADPAX issued an Aircraft Depainting Technology report indicating that Flashjet® was cost competitive with chemical as well as PMB paint strip methods while significantly reducing the hazardous waste stream. (See Report No NAWCADPAX—98-236-TR). Currently, the flashjet ® process has been approved by NAVAIR for the removal of organic coatings from metallic as well as monolithic polymer materials (See NAVAIR ltr SER AIR-434000A/7.3202 dtd 13 April 2000) Today, the flashjet® process is being used in a gantry application to strip the T-45 and AH-64 aircraft and F-15 radomes at Warner Robbins AFB. Based on FJ process approval for metallic structures and the characteristic large, flat surface area available on a P-3, the P-3 was viewed as an ideal candidate for the FJ process. However, the currently available FJ solution is limited to small aircraft and component stripping due to the 50’ design limit of the FJ gantry solution. Subsequently, the Mobile Flashjet ® Manipulator project was initiated to develop an effective, efficient Flashjet® process to de-paint large P-3 sized aircraft. *(See Plate 1 for Flashjet® process description.)*

2.3 Potential Benefits: Functional performance improvement including: (1) the FJ process is benign to the substrate, (2) no hazardous materials are employed in the process, (3) the process provides selective paint strip capability down to primer, (4) chemical or media intrusion potential is eliminated, (5) waste streams can be reduced dramatically, and (6) requirements for OSH monitoring of personnel can be significantly reduced.

3.0 Project Objective and Description:

3.1 Project Objective: To provide technology development and demonstrations that result in a production viable, vehicle based mobile manipulator employing the Flashjet® process to remove the surface coating from large P-3 aircraft.

3.2 Project Description: This Flashjet® Mobile Manipulator Development project was structured in four (4) phases to provide a systematic approach for the manipulator development while minimizing investment risk and providing program management approval/concurrence of the results of each phase prior to contracting for the next phase. In general, this project's statement of work required the development of a mobile flashjet® system that would be capable of removing the surface coating (8 mils nominal) from 90% of the outer mold-line surface of a P-3 Orion aircraft within 120 hours. This goal was derived based upon meeting current P-3 workload and through-put times of chemical stripping operations and assumes a two shift flashjet® operation with a requirement for one system. The four phases of the project are described as follows:

Phase I - 3 D Simulate/Design/Build/Demo the Mobile Manipulator

Phase II – Demonstrate Mobile Manipulator Reach & Maximum P-3 Paint Strip Potential/Generate Process Time & Cost Models

Phase III – Perform Live Paint Strip Technology Demonstrations/Validate Maximum Strip Potential, Process Time & Cost Models/Develop full CBA

Phase IV – Make Investment Decision/Acquire Funding/Procure Mobile FJ System

4.0 Phase I & II Demonstration Results:

4.1 Phase (I) Demonstration: Computer modeling and simulation by Framatome Technologies drove PaR System's design concept of the mobile manipulator. The final design models were used together with computer model of the P-3 to determine reach capability and estimates of process time study for phase I. Framatome Technologies, provided PaR systems a report of Robot Reach and Scan Time Study November 03rd, 2000. This report estimated robot reach (i.e.strippable area) at approximately 77% of the aircraft (approximately 5001 sqft) and estimated the associated strip time for this area to be approximately 99 hours. Platform move time and strip time was estimated at 12 hours and 87 hours respectively.

Subsequently, PaR systems was given approval to design and build the manipulator. *(See Plate 2 to for pictures of Mobile Manipulator with design features description.)* This resulted in a successful demonstration of the new manipulator (with mock-up of flashjet head) using a full-scale P-3 model of a fuselage and wing section on August 7th, 2001. During the demonstration safety features and interlocks of the mobile system were fully demonstrated. Both project manager and the Boeing Company (Prime Contractor) witnessed this demonstration. A video of the demonstration effort is available for review.

4.2 Phase (II) Demonstration: The Boeing Company provided the turn-key demonstration October 2001 at NAS JAX Hangar 114. *(See Plate 3)* A P-3 Orion aircraft was used to identify maximum reach and strip potential utilizing a 12" simulated stripping head assembly. Reach analysis during phase II showed improvement over Phase I simulation results. *(See Plate 4 for results comparison.)* Contractor report estimated robot reach (strippable area) at approximately 87% of the aircraft (approximately 5695 sqft) and estimated the associated strip time for this area to be approximately 103 hours. Platform move time and strip time was estimated at 5 hours and 98 hours respectively. Optimum aircraft configuration to ensure maximum strip area was identified as aircraft on jack-stands with landing gear retracted. The Boeing Company provided a full report on the Phase II Demonstration effort December 2001.

5.0 Phase (III) Demonstration Results:

5.1 General: Phase (III) three consisted of the FLASHJET System being assembled, tested, and set up for paint stripping demonstrations at the P-3 Orion aircraft maintenance facility (Hangar 101W) located at NADEP Jacksonville. Demonstrations occurred from February 19th to April 1st, 2003 utilizing P-3 (BuNO 161407) scheduled for early induction. Phase III utilized the contractor owned Mobile Manipulator, rented equipment and government procured equipment to make up a complete FLASHJET® Coatings Removal System. *(See also Plate 5 & 6 for MFJ facility and equipment arrangement during the demo period.)* The primary objective of Phase III was to demonstrate levels of FLASHJET System and Manipulator performance to validate the findings of Phase I and Phase II, and to provide data that supports justification to proceed with Phase IV and system procurement. The following acceptance criteria was established to fully evaluate the performance of the mobile flashjet system in a potential production environment:

- Achieve 80-90% strip capability with engines in place
- Achieve TAT < 120 hours from a single Mobile FJ system
- Verify TAT is competitive to Chemical Stripping or PMB
- Verify Total Process Cost is competitive to Chemical Stripping or PMB
- Verify MFJ Process Repeatability from Aircraft to Aircraft
- Verify User Friendliness of Controls, Software and Communications
- Verify MFJ System Reliability
- Verify A/C safety is assured
- Verify ESH Compliance of the technology

5.2 Summary of Phase III Results: A summary of demonstration results based on Acceptance Criteria above is provided as *Plate 7 & 8*. Problems identified during the demonstration are provided as *Plate 9*. MFJ system reliability and specifically the reliability of the mobile manipulator became a central issue during the to demonstration and for this reason is the centerpiece of the *Operational Performance Evaluation* below. In addition, a summary of results reported by Flash Tech is provided as *Plate 10*. Results show that process time projections are well within established goal of 120 hours but that the amount of strip continues to trend well below program target reach of 90%. Reach continues to be a major area of concern and reinforces the need for the contractor to develop a complete (100%) paint strip solution including the supplemental strip process to addresses the areas not reached by flashjet®. To their credit, Flash Tech has made a recommendation to supplement the flashjet® process with state of the art laser stripping technology and provides projected laser strip estimates. However, at this time subject laser system is considered developmental since it is not commercially available. Finally, *Plates 11 through 16* provide photos of FJ stripped areas of the P-3. While test panel strip results show uniform strip results, aircraft strip photos show that results from the FJ strip process can vary widely dependant upon previous corrosion repairs and surface treatments made on seasoned, operational aircraft in the field. *Plate 17* provides photos of FJ stripped area of the P-3 tail radome with excellent results. See MESR 03JX01532.

5.3 Operational Performance Evaluation: Unfortunately the demonstration period was significantly impacted by an over current condition for two of the seven mobile manipulator axis motors and due to the long lead-time for replacement of these motors, the amount of actual paint stripped from the P-3 was limited to less than 6%. Although stripping a large portion of the aircraft was a major objective of the demonstration, sufficient information was collected to predict that 84% of the aircraft could have been stripped in approximately 106 hours if subject motor failures had not occurred. [Following the demonstration, contractor investigation concluded that the cause of the failure as a motor brake solenoid that did not fully release. Later, root cause analysis showed that this problem was caused by extended storage in a non-environmentally controlled area.] The above estimates assume a system reliability factor of 90% which is in line with operational performance of the FJ gantry systems but may not be characteristic of an operational MFJ system.

5.4 Technical Evaluation of Flashjet® Paint Strip Results: The Materials Engineering Division (code 4.3.4) was requested to review final paint strip results and to determine the impact of those results on downstream corrosion inspections and subsequent process operations. Their detailed report is provided as MESR 03JX01532 (dtd 23 Apr 2003)and is summarized as follows. While it was observed that the flashjet® process effectively removed paint at acceptable strip rates (i.e. approaching 3 mils/pass) and that the final stripped surface allows recoating *without the requirement to completely remove all paint down to the aluminum substrate, s*ignificant secondary process deficiencies were observed:

- The flashjet® process was found to thermally degrade the aircraft's chromate conversion coating in areas of in service repair for corrosion *(See Plate 16)*. This deficiency necessitated that the damaged conversion coating be removed from these areas. Two available methods to remove this coating include (1) scotch brite cleaning [which was found to be labor intensive] or (2) use of chemical paint strippers. [Note, while the flashjet process was found to thermally degrade the aircraft's conversion coating, the metallurgical branch determined that the short time (approximately 1 sec) of thermal exposure at moderately low temperatures was not a concern with respect to substrate materials property effects.]
- Lack of an adequate, effective, environmentally friendly, *proven and available* touch up strip technology to reach areas not stripped by flashjet®. With the flashjet® process these areas typically account for a significant 15% of the aircraft and are the least accessible areas and include wing roots, etc. To address this issue, it was recommended that PMB and laser strip be investigated as supplemental strip technology options with the FJ system.
- Non-uniform appearance of the finished flashjet surface decreases ability to effectively identify and remove corrosion that can result in missed corrosion sites. To remedy this deficiency, it was recommended that infrared/mircrowave corrosion detection instrumentation be investigated.

- Inability of the FJ process to remove polysulfide sealant. For the P-3, 100% removal is required for corrosion inspection and is accomplished with a chemical desealer, TT-R-2918. However, use of chemical desealer is not compatible with the FJ process because it adversely affects performance of remaining primer left by flashjet. This fact negates a significant benefit of the FJ process. As an alternative, PMB effectively removes seam sealer and would be more compatible with the FJ process. Unfortunately the PMB strip facility at Jacksonville is limited to fighter-sized aircraft only.

5.5 Phase III Process Time Study: During Phase III, the Process Engineering Division(c/6.3.1) conducted an analysis of the overall process time of the flash jet process versus the current chemical strip process as well as a potential PMB strip option (although no PMB facility exists to exercise this option for the P-3). As recommended by the Materials Lab subject time analyses were adjusted for process deficiencies noted above. A further FJ versus PMB comparison was made for the EA-6B as a potential workload for a MFJ system. Results of these process time studies are provided on *Plate 18.* In general, the current P-3 chemical strip process including preparation, strip, corrosion treat, conversion coat is accomplished in 6 days. Based on results of the MFJ demonstration effort and assuming the predicted maximum P-3 strip at approximately 84% with flashjet® and assuming the remaining surface is stripped with chemical, the estimated elapsed or total process time would be approximately 12 days. For flashjet® supplemented with PMB the total P-3 process time is estimated to be even longer since it is a more labor-intensive process. [In addition, previous PMB experience with the P-3 has shown that PMB poses a greater risk than chemical with respect to damage of P-3 thin skin areas as well as a greater potential risk for PMB intrusion into engines, aircraft and components.] Similarly, the current EA-6B strip process time including preparation, strip, corrosion treat, and conversion coat is 7 days. If the flashjet process were used on an EA-6B (80% strip) and PMB used to supplement FJ at 20%, the estimated total process time would be 10 days total. This estimate assumes that NAVAIR will fund, finish the remaining testing and approve FJ for strip of honey-comb structures (i.e. these structures account for approximately 15% of the EA-6B). The above estimates also assume two shift FJ operations and a 90% FJ reliability with repair and maintenance of the FJ system on the 3rd shift. Although this degree of reliability was not observed during the demonstration it is considered reasonable based upon Flash Tech making suggested hardware improvements, ensuring appropriate spares are stocked and assuming that the MFJ performance reaches the reported operational performance of flashjet® gantry systems at NAS Kingsville, Mesa, and Warner Robbins facilities.

5.6 Phase III Process Cost Study: Based upon process time studies above, the process engineering division likewise developed P-3 cost comparison of Chemical Stripping to MFJ supplemented with Laser and, as an alternative, MFJ supplemented with Chemical strip. Similarly, an EA-6B cost comparison was made comparing PMB strip to MFJ supplemented with PMB. *(See Plate 18)* Results show that Flash Tech's MFJ system coupled with laser strip is cost competitive with current chemical strip cost, particularly when water treatment costs are added and the amount hazardous materials used and the waste stream is considered. However, when Flash Tech estimates are adjusted for the significant FJ process deficiencies noted above and the inherent risk associated with an as yet unproven laser strip technology is considered, the chemical strip solution for the P-3 continues to be the best option. For the EA-6B the comparison is a little closer since PMB is a dry process and therefore more compatible with flashjet®. However, Flashjet® cost is still higher. In either instance, existing strip methods continue to be fully ESH compliant, program offices are satisfied with existing processes and existing strip methods continue to provide the best strip results with least process time. Additionally, the MFJ procurement cost estimated at $2.9M cannot be justified when satisfactory strip methods are already in place. Note however that with chemical strip process, water treatment costs are not included in unit pricing but are ultimately included as an overhead cost and the tendency is to overlook needed water treatment repairs or improvements that are vital to chemical strip operations. Therefore, the NADEP should not overlook the state of the water treatment system but plan for its continued maintenance and/or required upgrade in support of the complete chemical strip process. To that end, a 2003 recommendation to renovate TP 2 (which was projected to yield significant cost savings and greatly reduce the amount of hazardous materials used and waste stream generated) should be revisited. Likewise with PMB the NADEP must continue to seek state of the art equipment to minimize personnel exposures and remain vigilant in retaining certified vendors to recycle hazardous media waste to ensure the PMB option remains viable into the future. It should be noted that in CY 2002 at 27 a/c the P-3 chemical strip process accounted for 324,000 gal of rinse water use at a cost of $276,102 and is associated with 77,571 lbs hazardous waste. Additionally in the same year PMB waste stream associated with 39 fighter aircraft accounted for recycling 607 drums (194,240 lbs waste) at a cost of $250,388. Finally, if past ESH regulations and trends are any indication, future ESH requirements will continue to become ever more restrictive and current chemical and PMB strip solutions which are compliant today may not be tomorrow. Therefore, it is recommended that the Navy continue to actively seek production viable alternatives for aircraft and large component paint stripping. (Refer to LMTCE NAS #103 & #107 at www.enviro-navair.navy.mil)

5.7 Composite Strip Potential: As a final and very significant finding, the materials lab determined that the flashjet® technology was very effective at removing the surface coating of the polyester fiber reinforced plastic of the P-3 tail radome “stringer”. *(Refer to Plate 17.)* See also MESR 03JX01532. Based on this data point, the materials lab recommended that the flashjet® process would be best suited for stripping composite surfaces such as the P-3 and EA-6B radomes, P-3 tail radome and other large composite aircraft surfaces and specifically those which exhibit difficulty and/or damage with existing chemical and/or PMB process methods. The materials lab further recommended that epoxy and polyester, fiber reinforced plastic (composite materials) structures and/or components should be considered suitable for coating removal by Flashjet® and that recurring problems with damage to such structures during coating removal with PMB, chemical and sanding processes could be significantly reduced or eliminated. It was noted, however, that Navair approval for subject composite surfaces is not available at this time and that specific NAVAIR approvals are needed before the flashjet® process could be fully employed in these instances.

6.0 Recommendations: Based on discussion above the following recommendations are provided:

- At this time based on (1) current ESH compliance of existing Chemical and PMB processes as well as (2) the uncertainty of stripping the remaining 15% not stripped by flashjet® and (3) the several secondary the flashjet® process deficiencies noted above (i.e. observed thermal degradation of conversion coat by flashjet® in areas of in-service repair (This deficiency required that subject conversion coat be removed) and the decreased ability to inspect for corrosion damage due to non-uniform appearance of the post flashjet® stripped surface), it is <u>not</u> recommended that the depot proceed with Phase IV. In addition, and as a direct consequence of deficiencies noted above, it has been shown that the MFJ process would be neither cost nor process time beneficial if the FJ process were coupled with either chemical or PMB strip processes. Finally, while there may be some merit in continued development of the MFJ system to achieve significant hazardous material and waste stream reductions for aircraft and as a hedge against future ESH compliance issues, there still exist several technology risks associated with Flash Tech's MFJ paint strip solution. These include: (1) satisfactory resolution of the reliability issues noted during the demonstration, (2) successful integration of Flash Tech proposed infrared position location technology and (3) successful integration of an as yet unproven laser paint strip technology with flashjet®.

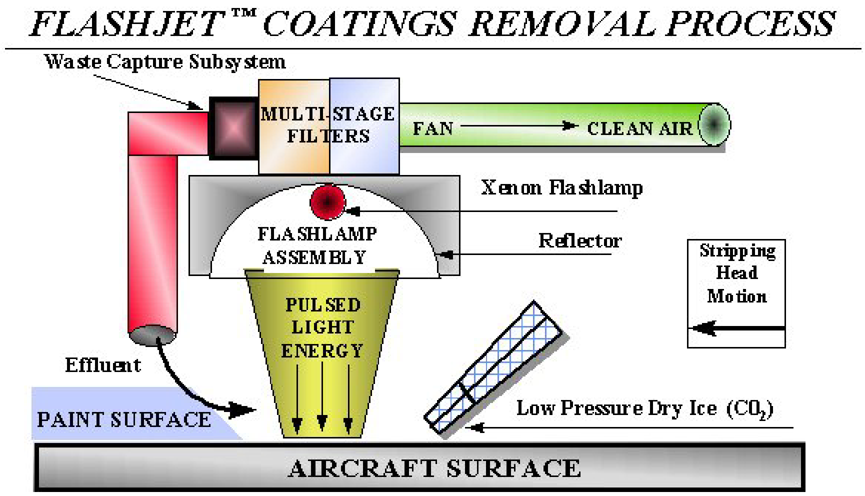
- However, based upon material lab recommendation above, it is recommended that flashjet® process (or other thermal process such as laser stripping) be pursued as an alternative for stripping composite surfaces such as the P-3 and EA-6B radomes, P-3 tail radome and other large composite aircraft surfaces and specifically those which exhibit difficulty and/or damage with existing chemical and/or PMB process methods. During FY93 through FY03 over 173 radomes supporting EA-6B, F-14, P-3 and H-60 programs were reworked at NADEP JAX. Additionally, potential F-18E/F and JSF workload should be considered. Such a facility could be designed to handle all radome work for the Navy and not just current depot workload. To further validate the potential benefit of this flashjet® solution, recommend further discussion with Warner Robbins AFB and a site visit to the Radome FJ strip facility. Additionally, this recommendation should be validated through appropriate platform, engineering, and production offices. Accordingly, it is recommended that all potential workload be determined and an appropriate cost benefit analysis be generated based upon the potential workload, needed working envelope for subject components and properly sized FJ gantry technology solution. In support of this workload, the materials engineering division must identify and establish a test plan to achieve all requisite NAVAIR approvals and establish process specification requirements.

- Although the depot continues to take positive steps to increase efficiencies of PMB and Chemical strip operations, increase personnel safety and reduce hazardous material and waste, ESH drivers and trends continue to be ever more restrictive. Additionally, employment of these existing paint strip methods even with increased efficiencies will continue to account for the largest source of hazardous material use and hazardous waste discharge at the depot. Therefore, it is recommended that the Navy continue to actively seek production viable alternatives for aircraft and large component paint stripping to ensure the depot can meet customer needs into the future.

- PMB and Chemical paint strip solutions have inherent ESH concerns that must be mitigated and monitored to ensure compliance. Process equipment as well as support processes must be supported with state of the art technology to reduce personnel exposures, reduce hazardous material use and reduce hazardous waste as much as technology will allow. To the depot's credit, a new PMB aircraft strip facility will be installed in early FY04 that will significantly reduce the amount of PMB used and PMB waste generated. Likewise, the depot's chemical waste stream can be greatly reduced by implementing measures to control the amount of rinse water and to improve treatment plant efficiency. To this end, it is recommended that Water Treatment Plant #2 upgrade recommended by the materials lab (Mr. J. Adams) be re-reviewed in terms of the economic as well as the environmental benefit it would provide to the depot's chemical strip as well as component surface treatment operations. *(This upgrade reports potential waste stream reduction of 90%,* ***Total Cost as $1.7-2.0 M, with Minimum Annual Savings of $700k and Payback of 2.4-2.9 years)***

- Finally, with regard to disposition of flashjet® technology equipment owned by NADEPJAX, it is recommended that subject support equipment be held in storage (currently located at Cecil Field Hgr 1845 & Orange Park Warehouse) until a decision is reached regarding the need for a Navy composite FJ strip facility at Jacksonville as proposed above. If such a facility is needed, previous procurements will save substantial funding required. If the facility is not needed, an alternative recommendation would be to offer this equipment at no cost to Warner Robbins as a backup to their FJ radome facility or to support Air Force interest in MFJ technology demonstrations to solve Air Force paint stripping problems.

Plate 1: Phase I Flashjet® Process Description



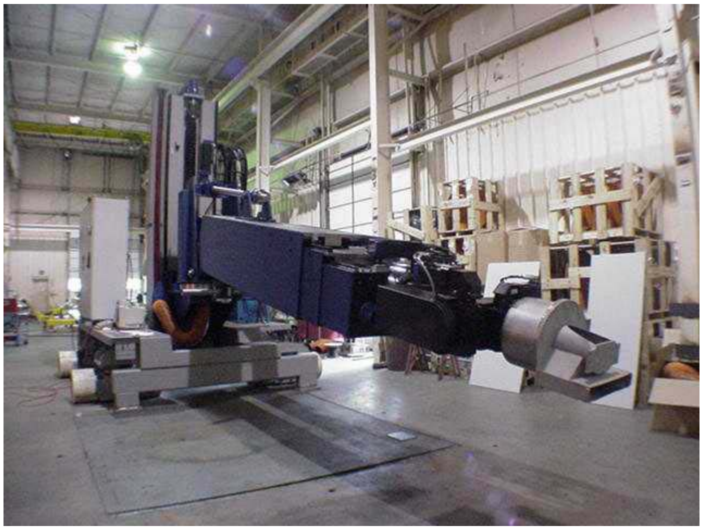
Synergism of Pulsed Light and Dry Ice

The pulsed light energy source, a xenon flashlamp consists of a 12" long quartz tube filled with xenon gas that emits short pulses of light energy. As the coating absorbs this photon energy, its temperature rises rapidly to ablate the coating. Rapid four cycle per second pulsing of the lamp while the stripping head traverses the part results in excellent coating removal rates (up to 3-4 mil/pass at 1"/sec). As the coating undergoes ablation, the resulting residue is simultaneously swept from the surface with low pressure dry ice stream and collected by an effluent capture system. The heating effect of the photon energy is continually being offset by the dry ice particle flow. The effluent capture system filters and treats the waste stream before returning it to the atmosphere.

The amount of paint removed from an area of substrate is approximately proportional to the energy delivered to the area, so the rate of removal is proportional to the power. This energy can be applied more or less rapidly by operating at higher or lower input voltage and pulse rate with correspondingly shorter or longer removal rates. A separate variable, which can be used to vary the the removal rate, is the stripping-head traverse rate. A given energy can be delievered to an area by operating at high input voltage at a rapid traverse rate, or by using a lower input voltage and moving the head more slowly. A slower removal rate may provide finer control over the strip depth and minimize heating of delicate substrates.

A major advantage the Flashjet® system has over other coating removal methods is the degree of control achievable. Through adjustment of the operating parameters (i.e. light-energy density, traverse rate, etc.) varying degrees of coating removal are possible, including complete coating system (topcoat and primer) removal or topcoat only. This selective coating removal is extremely attractive for composite substrates, whereby leaving the primer intact precludes any possible substrate damage.

Plate 2: Phase I Mobile Manipulator



Key features of the mobile manipulator are:

Cart Control: Drives cart through a hand held pendant at rear end of cart. Cart has four sets of wheels and is driven by hydraulics through two wheel sets. Opposite wheel sets are idlers. Due to the unique design, cart is capable of being driven in any direction. Wheel sets can be extended to move and retracted to establish robot control over a sturdy three-point base.

Robot Control: A hand held pendant at robot end of cart allows operator to teach and program aircraft surface areas through three dimensions. Robot controls seven robot axis movement and is interlocked with cart pendant to ensure no dual movement.

Robot Axis & Range of motion:

1st axis: Boom rotate – 45 to + 45
2nd axis: Boom pivot – 15 to + 60
3rd axis: Boom extend to 27 feet
4th axis: Theta 1 (yaw) – 185 to + 185
5th axis: Theta 2 (pitch) – 135 to + 135
6th axis: Theta 3 (roll) – 225 to + 45
7th axis: Boom elevator to 11 feet

A/C collision safety:

Manual Emergency Stop
Laser beam E-stop switch located along underside of boom
Halo (360) E-stop protection around Flashjet head.
Remote boom cameras enhance operator control/visibility.

Flashjet® Process Control: Windows Driven System w/remote control console providing full status, interlock and control of support systems as well as robot control and program review features. Laser stand-off distance sensors provide teach and auto surface tracking capability. Color vision sensing system provides auto-selective strip capability. IR scanning system provides surface temperature monitoring, control and track history.

Plate 3: Phase II MFJ Demonstration Hangar 114

Plate 4: Phase I vs Phase II Comparison

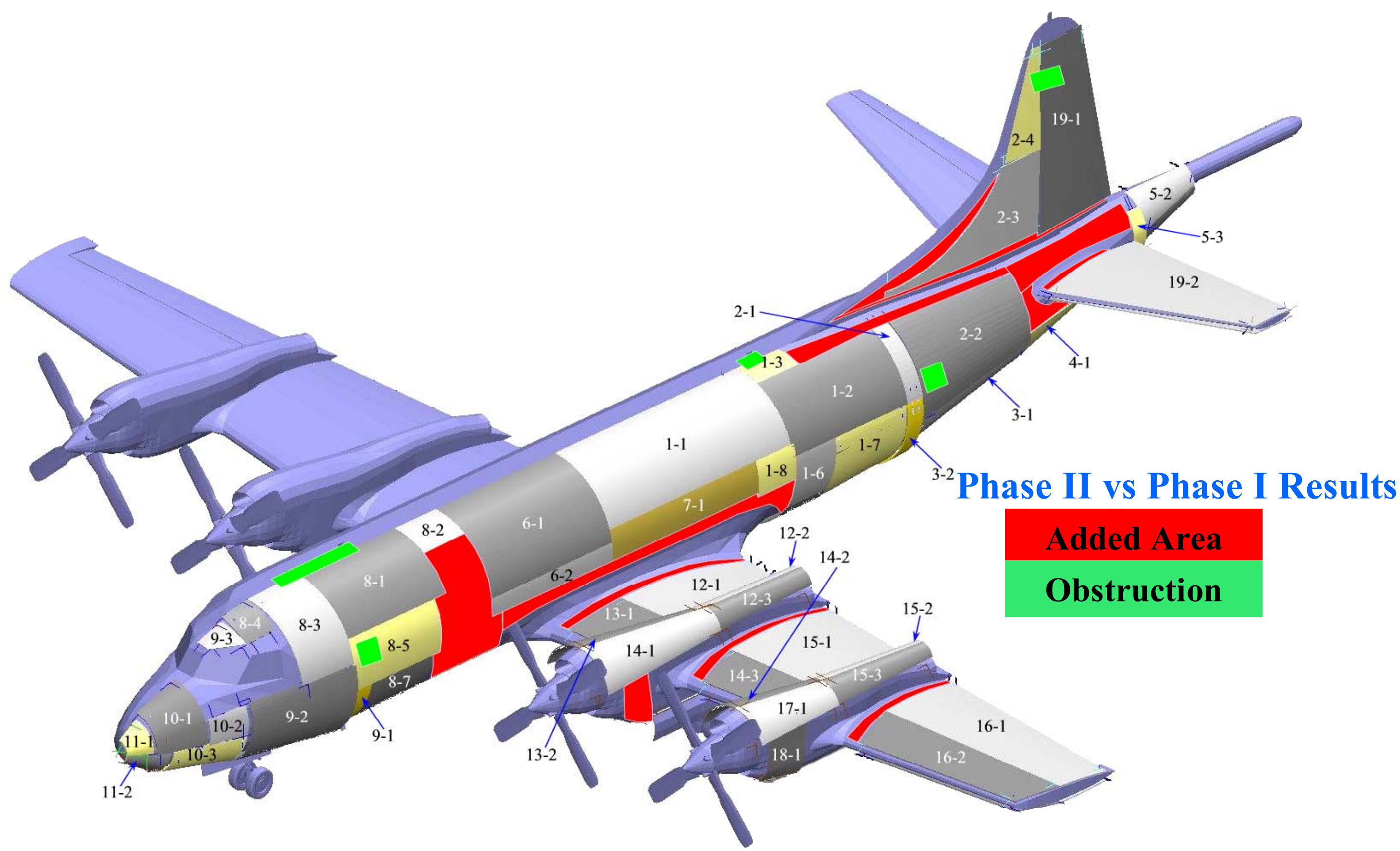


Plate 5: Phase III Equipment Configuration and Demo Arrangement

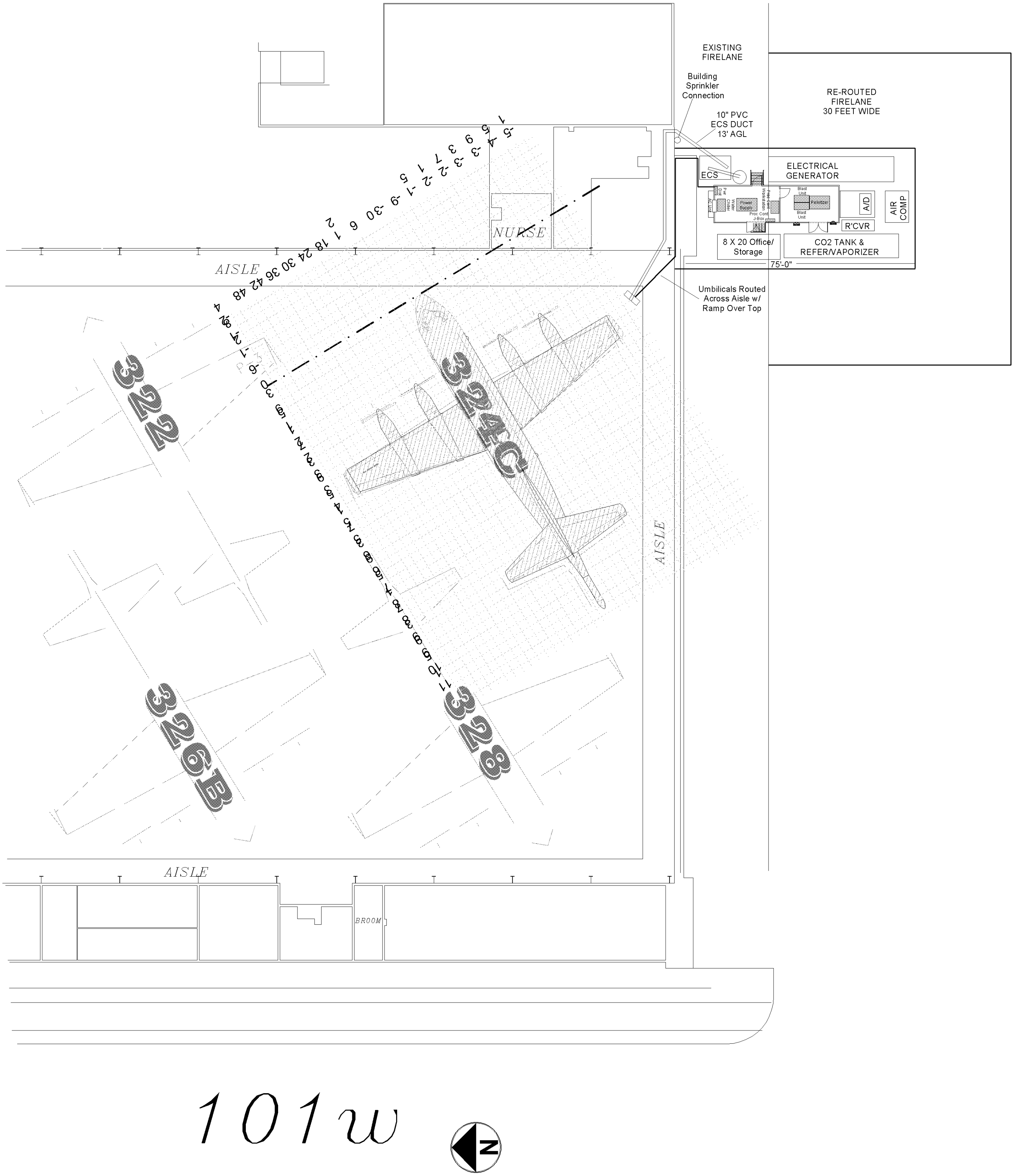


Plate 6: Phase III System Demonstration Hangar 101W

Plate 7: Phase III Test Panel Results:

Panel FJ Strip Analysis	Acceptance Criteria	Actual Result	Observer	Comment
Measure Coating Thicknesses	N/A	Various	Benfer	6 mil = A/C average
Validate FJ Strip Area #1 (sqft) Calc.	Little to no variation from actual	SAT	Flash Tec, Inc. & Cowherd	Verified FJ Calc vs Actual for test panels & various program areas
Validate FJ Strip Area #2 (sqft) Calc.	Little to no variation from actual	SAT – see (File 14.005 calc vs actual)	Flash Tec, Inc. & Cowherd	FJ Calculated = 21.595 Actual Measured= 22.75 Calculated is conservative
Validate Temperature Control Feature	Temp Control vs Actual	SAT	Benfer, Youngers Barilla	Verify temp w/hand held & saturation temperature w/ pencils & thermocouples
Capability to strip paint scheme #1	> or = 3 mils/pass; Strip t/primer	3mil/pass @ 2300 V	Benfer/Cowherd	Flat or conventional grey
Capability to strip paint scheme #2	> or = 3 mils/pass; strip t/primer	3mil/pass @ 2300 V	Benfer/Cowherd	Gloss gray
Capability to inspect paint scheme #1	Little to no impact on inspection	See MESR 03JX01532	Benfer	Investigate w/FST; E & E
Capability to inspect paint scheme #2	Little to no impact on inspection	See MESR 03JX01532	Benfer	Investigate w/FST; E&E
Capability to strip seam sealer	100% strip required	See MESR 03JX01532	Benfer	Evaluate Seam sealer strip result & ease to remove following flashjet strip
Verify FJ Control & Safety features	Meet or Exceed control & safety	SAT	Cowherd	Robot/Cart as well as Support Equipment Status, Safety inter-locks verified
Compliance with FJ Process Spec.	FJ Process Spec per Navair letter Ser AIR 434000A/73202 Dtd 13 April 2000	SAT See MESR 03JX01532	Benfer/Cowherd	Substrate temperature controlled; however temp spikes observed

Comments: Test panel testing was successfully completed March 17th and 18th. Based on test panel results, Nadep materials lab, c/4.3.4 approved the use of the FJ system to start stripping the aircraft. NAWCADPAX witnessed demo on 3/26 and reviewed test panel results c/4.3.4. As requested by NAWCADPAX temperature pencils were used to validate temperature control feature of imbedded flash jet equipment.

Plate 8: Phase III Demo Acceptance Criteria & Results:

Objective	Acceptance Criteria	Actual Result	Observer	Comment
Measure A/C Coating Thickness	N/A	6 mil avg	Benfer	See MESR 03JX01532
Area Stripped (sqft); Total A/C = 6487	> or =5643 sq ft	370 sqft	Cowherd	Flash Tech predicts 5449
% Strip (Strippable Area)	> or = 87%	5.7%	Cowherd	Flash Tech predicts 84%
FJ Process Time Analysis	< or = 100 hrs	8:08:25 h:m:s	Cowherd	Estimate @84% = 113hrs
FJ Process Cost Analysis	< or = x $'s	$3.40/sqft/3mil		See Flash Tech report
Program Repeatability f/aircraft to aircraft	Programs readily X-form	SAT	Cowherd	Tail, Fuselage & Engine Cowling Programs Trans-formed sat after aircraft move
% P-3 area that is not repeatable from a/c to a/c and would require new reprogramming each time	< 10%; Evaluate process time	Unknown; Estimate 5-10%	Cowherd	Requires further evaluation w/P-3 Office & Flash Tech
Friendliness/Reliability:				
Flash Jet User Screen (Windows driven Flashjet & Robot Control Screens)	Friendly? (y/n); Reliable (y/n)%	F-Y ; R- ?	Cowherd	R- Interruptions of communication/control experienced; shielded cable improved situation; Fiber Optics needed
Robot & Pendant	Friendly? (y/n); Reliable (y/n)%	F-Y ; R- ?	Cowherd	R- #2, 3 axis motor overload problem; #2 axis gear box failure
Cart & Pendant	Friendly? (y/n); Reliable (y/n)%	F-Y ; R-Y	Cowherd	F- Need slow speed setting for cart moves
CO2 Pelitizer Unit	Friendly? (y/n); Reliable (y/n)%	F-Y ; R- ?	Cowherd	R- Insufficient run time to fully evaluate
Power Supply Unit	Friendly? (y/n); Reliable (y/n)%	F-Y; R-Y	Cowherd	Initial problem with maintaining simmer voltage corrected
ECS Unit	Friendly? (y/n); Reliable (y/n)%	F-Y; R-Y	Cowherd	See Ops Data below
Lamp Cooling Supply Unit	Friendly? (y/n); Reliable (y/n)%	F-Y; R-Y	Cowherd	Initial problem w/Refr Compr failure corrected.
UMS	Friendly? (y/n); Reliable (y/n)%	F-? ; R- ?	Cowherd	F & R -Hose subject to collapse w/o additional support; manpower

				required to move is frequently in excess of 2
A/C Safety	FJ Equip/Ops ensure A/C safety	SAT	Cowherd	Safety features verified prior to a/c strip. However, failure of any axis motor limits strip to lower have of aircraft to ensure aircraft safety.
A/C Surface Temperature Control	Maintain Temperature w/i limits	SAT	Cowherd	Temp spikes observed above control setting; See MESR 03JX01532
Environmental Impact	Meet or Exceed Requirements	SAT*	Cowherd	Pre-filter sampled and determined to be Haz Waste. Report available.
Haz Mat & Haz Waste Reduction	85% Reduction vs chemical	SAT	Cowherd	No Haz Materials req'd; One filter change observed; Est total Haz Waste = 14 pre-filter changes; 1 drum/aircraft
Safety & Health: Eye, Ear & Skin	Meet or Exceed Requirements	SAT	Cowherd	** See reqmts below
Safety & Health Monitoring	Determine % reduction FJ vs chemical	TBD	Cowherd	Evaluate based on type & amount of supplemental strip required ***
Nadep Engineering Process Time Analysis of FJ Demonstration:	< or = Chem Strip (96 hrs)	113 hours based on limited data collected, assumes 84% strip	Cowherd	Demonstration cut short due to Robot axis motor problems; Total process time analysis is estimated based on data recorded. Does not include time to strip remaining areas (16%)
Total Strip Time	< 80 hours	3:28:37 h:m:s	Cowherd	c/631 FJ Time Study Report Available
Total Time f/approach, escape & index	< 15 hours	4:10:24 h:m:s	Cowherd	c/631 FJ Time Study Report Available
Total Floor Positioning Time	< 5 hours	0:29:24 h:m:s	Cowherd	c/631 FJ Time Study Report Available
Total Process time	< 100 Hours	8:08:25 h:m:s	Cowherd	Estimated at 113 hrs based upon 84%(5449ft2) strip

* ECS Observed operational readings: Prefilter DP=0.75"; HEPA Filter DP=4.0"; Vacuum = 60" H2O; Flow= 2200CFM; Complete Pre-Filter change out required after approximately 8-10hrs of productive flashjet stripping operations. The two 2'x4' pre-filter elements were removed and placed in Haz waste drum provided by Environmental office. Based on area stripped, 14 prefilter changes would be required for a P-3. It is estimated that at 84% strip the entire pre-filter waste for one P-3 would fill only one drum. During disassembly of the UMS following the demo a significant accumulation of paint ash was observed at low points of the suction pipe. Flash Jet plans to address this issue by installing of a type of cyclonic separator at or near mobile manipulator. It is hoped that this mod will also reduce the number of pre-filter changes required. A sample of the prefilter waste was taken for analysis and was determined to be Hazardous waste. A report is available.

** Documented Safety Requirements for Flashjet® process are: (1) Light: skin & eye protection from UV light within 20 feet, (2) Noise: single ear protection w/i 25-35 feet; double ear protection for operators. (2) CO2 5000ppm (8hr TLV). CO2 monitors were placed in both the Pelitzer space and in the demonstration area to ensure visiting personnel and operator safety. Ear & eye protection devices were provided to those in the operating areas.

*** Safety Office is concerned about the supplemental strip technology that would be coupled with flash jet. With respect to technology ranking versus personnel exposure, the Safety Office identifies chemical strip with the least exposure, followed by PMB and then hand sanding. According to the safety office, hand or vacu-sanding represents the greatest potential personnel safety hazard. Since chemical strip is a wet process it is the least desirable process to supplement Flashjet. Therefore, the best technology with FJ would be PMB. Unfortunately a PMB facility is not available for the P-3 at Jacksonville.

Plate 9: Problems Identified During Phase III Demo:

Flashlamp Simmer Power Supply regulation deficiencies caused loss of Flash lamp. Kaiser representative was brought in and made various adjustments to correct deficiency. No further problems were experienced throughout the remained of the demonstration.
FJ Control cables – During FJ operations numerous intermittent control problems were experienced. Short term corrective action was to install shielded cable and ground circuits. Per Flash Tech and PaR systems long term corrective action is to install fiber optic cables.
UMS - Flexible hose connections are subject to collapse. Redesign is required. Flash Tech investigating alternatives. In addition, Flash Jet is investigating installation of a type of cyclonic separator at or near mobile manipulator to reduce the amount of ash residue deposited along the length of the UMS system and to reduce the number of pre-filter changes. A sample of the prefilter waste was taken for analysis. Sample was determined to be Hazardous waste. Report available upon request.
Lamp Cooling Water Supply Cabinet – Heat discharge from this unit during FJ strip operations produce heat loads to great for enclosure/space a/c unit. Enclosure/space a/c unit is under-size for actual heat load. Temporary fix is to open enclosure doors and install floor fan to ensure adequate ventilation. Long term fix per Flash Tech is to relocate unit to same room as CO2 pelitizer.
Temporary Air Compressor – 3/20 Impact of failure on FJ operations minimal. However, tech rep had to replace a temperature transducer.
Temporary CO2 Tank – 3/20 Refrigeration Compressor failed; compressor required replacement. Interim fix was to manually relieve pressure to maintain cooling and to sustain Flash Jet Operations. Repair complete 3/21.
MFJ Robot's 2nd (pitch) axis gearbox and motor. On Wednesday, March 19th during stripping of the fuselage, the Mobile Flash Jet Robot experienced high current/over temp of the MFJ Robot's 2nd (pitch) axis gearbox and motor. Repair assessed with PaR. Failure may be either infant mortality or design. Flash Tech/PaR requested to investigate. Load calculations were subsequently reviewed and determined satisfactory. Repair complete gear box replaced and 2nd axis motor exchanged with 1st axis motor. Over load/temp of motor (theorized) due to motor brake not fully releasing. Requires further investigation. Also need to resolve if repairs affect programming as well as identifying recommended spare parts inventory for the MFJ system (including motors, breaks, gear box, etc. Approximately 2.9 hours (elapsed) productive time recorded on the MFJ system at this time.
MFJ Robot 3rd (boom) axis motor On Thursday, March 28th the 3rd axis motor tripped on high current. PaR indicates motor failure is probably due to motor brake not fully releasing. PaR to make full (root cause) investigation and identify corrective action to provide requisite reliability and review potential to provide access port for repair/replacement of 3rd axis motor. PaR later determined that a new access port was not needed to make a timely repair/replacement of this motor.
Peletizer Room needs more ventilation to ensure operator safety. Flash Tech plans to install additional ventilation to ensure safety of personnel.

Plate 10: Summary of All Demo Results by Flash Tech

Table shows the comparison between the *Program Goal*, *Phase I Simulation*, *Phase II Findings, Phase III Goal*, *Phase III Findings, and Phase IV Projections.*

Table A – Program Goal vs. Phase Comparisons

Reference	% Stripped	Platform Move Time (Hrs)	Strip Time (Hrs)	Total TAT (Hrs)	Square Feet	Strip Rate (Sq. Ft./Hr.)
Program Goal	90			**120**	**5838**	**48.65**
Phase I Simulation	77	12	87	**99**	**5001**	**50.52**
Phase II Findings	87.7	5	98	**103**	**5695**	**55.29**
Phase III Goal	87.7	5	98	**103**	**5695**	**55.29**
Phase III Findings (1)	84	9	97 (2)	**106**	**5449**	**51.41**
Phase IV Projections	84	9	121 (3)	**130** (4)	**5449**	**41.92**
Phase IV Projections w/Improvements (3)	85	7	97	**104** (5)	**5514** (5)	**53.02**

(1) Findings are projected based on available Phase III Data
(2) *Strip Time (Hrs)* were at two strip passes to remove 6 mils
(3) Assumes three strip passes to remove 8 mils
(4) Assumes no Phase IV improvements to either *Platform Move Time (Hrs)* or *Strip Time (Hrs)* that may reduce the *Total TAT (Hrs)*
(5) Assumes Phase IV improvements implemented to both *Platform Move Time (Hrs)* and *Strip Time (Hrs)* that reduce the *Total TAT (Hrs),* and a *% Stripped* improvement*. Also assumes new head traverse rate of 1.35"/sec vice 1.0"/sec travel rate.*

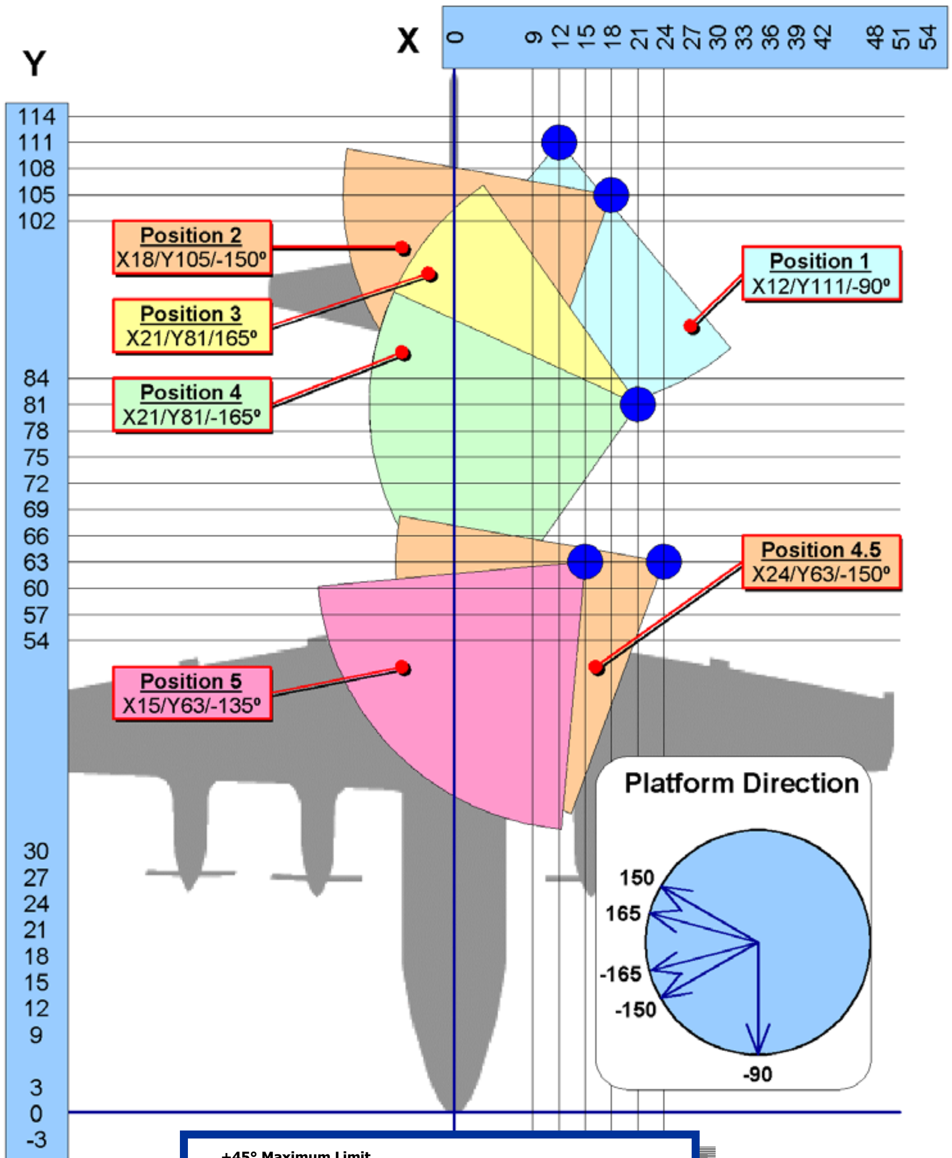
To remove the remaining portions of coating left behind after the FLASHJET Process, a complementary laser ablation process is proposed. This process provides much of the advantages of the FLASHJET Process and includes: (1) Selective Stripping, (2) Clean Process, & (3) User Friendly

The laser stripping process can start concurrently with the FLASHJET Process. Worker(s) can operate the hand-held laser in an area away from FLASHJET Stripping, with just eye and ear protection. Table shows a comparison between the FLASHJET and the laser processes. Note that the Laser Process Strip Time of 81 Hours is concurrent FLASHJET Process Strip Time. As it is with all coating removal processes, removing 100% of the P-3 Surface Area is unlikely, though the exact amount should be close to the 100% value.

Table B – Process Comparison

Area Removed By	Surface Area (Total = 6487)	% of Total	Strip Rate (Square Ft per Hr)	Strip Time (Hrs)
FLASHJET Process	5514	85%	53	104
Laser Process	973	15%	12	81

Plate 11: Phase III Stripping Plan
Port Side Platform Position Map (Platform locations 1-5)



Robot Work Envelope

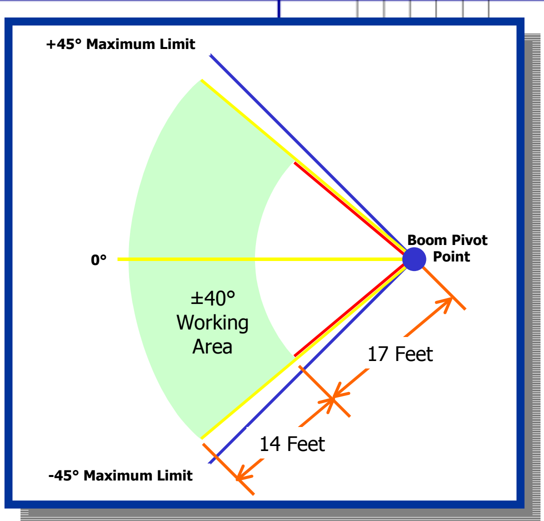
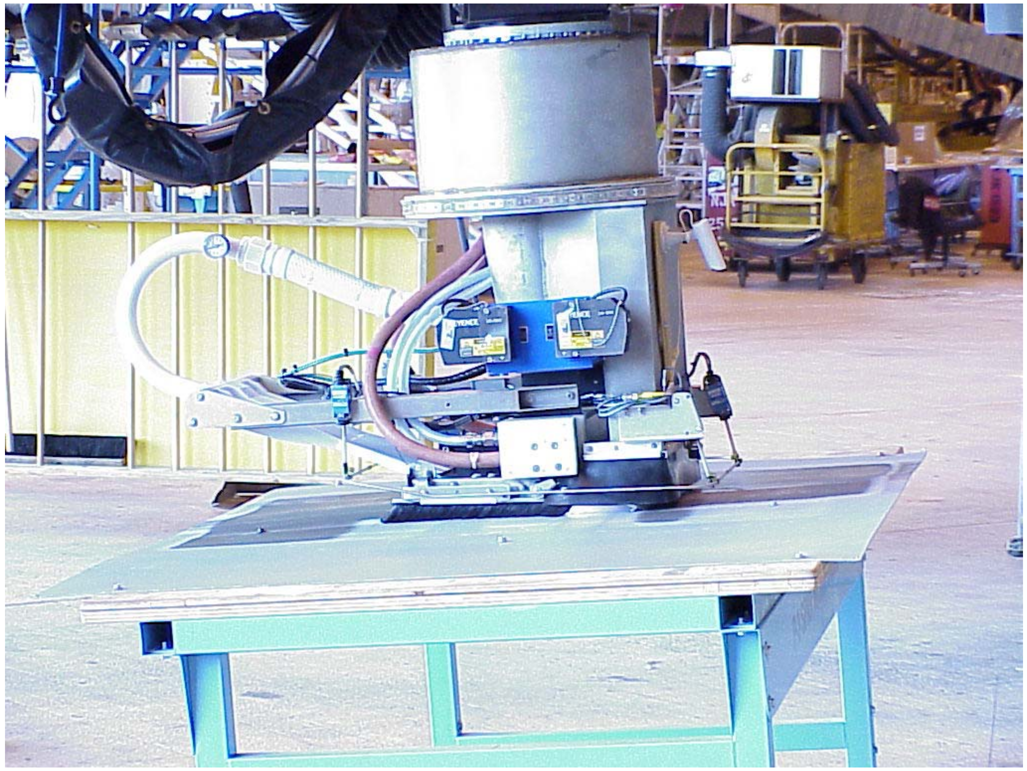


Plate 12: Current N-Haps Chemical Strip Process

Plate 13: Flashjet Strip of Test Panels



Note uniformity of strip down to base metal. This result was consistent during all demonstrations of test panels.

Plate 14: Aft fuselage being stripped by Flashjet

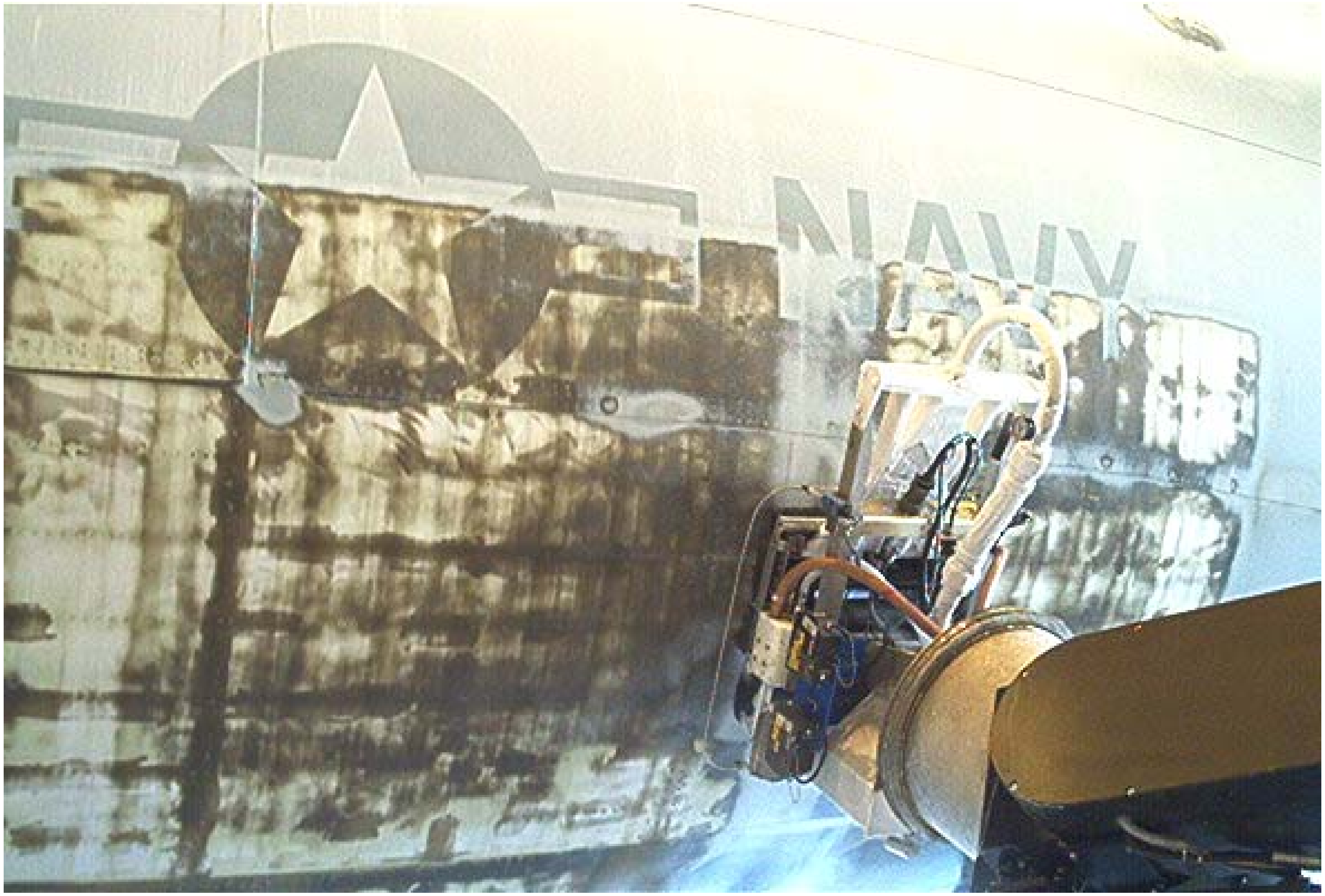


Plate 15: Flashjet Strip of Fwd Port Fuselage

Plate 16: Completed Flashjet Strip of Aft Port Fuselage

Note: (1) The above picture is a typical result of the flashjet® process over an aircraft which has been "seasoned" by field service repair. During demo the MFJ temperature control feature was set at 250F. Dark brown areas indicate thermally damaged conversion coat at the 250F setting. Lab panel test at right confirms thermal damage *(on right)* at temperature of 250F. (2) Identified chalked areas are the result of a corrosion inspection that identified these areas as positive for corrosion and will requiring glass bead blast to treat these corrosion sites. (3) The area around the lower right antennae is representative of the limit of FJ to reach/strip around obstructions but demonstrates FJ capability to "feather edge" strip areas into painted areas typically done by hand sanding.

Plate 17: Completed Strip of P-3 Composite Stinger

Notes: The flashjet strip process yields a uniform and damage free strip of P-3 (Honey-Comb Fiberglass) stinger. Materials lab subsequently recommends that epoxy and polyester fiber reinforced plastic (composite materials) structures/components should be considered for coating removal by FlashJet and that ideal candidate are those currently showing difficulty and damage with existing chemical, PMB or hand sanding depaint process methods.

Mobile Fashjet® Phase III Demonstration Report

Plate 18: Strip Time/Cost/Hazardous Waste Comparison

Table A: Strip Method Process Time/Waste Comparison

	Labor Hrs	N-Prod* Time (hrs)	Prod Time (hrs)	Elapsed Time (hrs)	Elapsed Time (days)	Estimated Hazardous Waste
P-3 Chem Strip	535	40	104	144	6	11,073 lbs
P-3 MFJ/Chem Strip (85/15)	711	88	180	286	12	9737 lbs
P-3 MFJ/Laser Strip (Flash Tech)	312	74	104	178	7.5	100 lbs
P-3 MFJ/Laser Strip (Adjusted)	699	80	168	248	10.4	9258 lbs
EA-6B PMB Strip	489	48	114	162	7	12,350lbs
EA-6B MFJ/PMB Strip (80/20)	469	72	161	241	10	9275lbs

* Based on 2 shift operation the 3rd shift is non-productive

Table B: Strip Method Process Cost Comparison

	Material Cost	Labor Cost	Maintenance Cost	Utilities Elec/Stm/Air	Water Trtmt Plt	Flashjet®	Total
P-3 Chem Strip	$12,022	$37,450	$520	$104	$10,226	N/A	$60,322
P-3 MFJ/Chem Strip (85/15)	$9448	$35,770	$460	$92	$5112	$36,846	$87,728
P-3 MFJ/Laser Strip (Flash Tech)	**	**	**	**	-	$46,057	$46,057
P-3 MFJ/Laser Strip (Adjusted***)	$8161	$34,930	$460	$92	$3408	$46,057	$93,108
EA-6B PMB Strip	$9975	$37,450	$448	$1600	N/A	N/A	$49,730
EA-6B MFJ/PMB Strip (80/20)	$5695	23,030	$84	$48	N/A	$25,154	$54,018

** Flash Tech estimates include all material, labor, maintenance & utility costs.
*** Flash Tech estimates have been adjusted to allow comparison of strip methods and reflect total process costs including corrosion treatment and conversion coat costs.

Note: Except for "(Flash Tech)" estimates above, all time and cost estimates include the total process time and cost to: prep, paint strip, corrosion treat, and conversion coat subject aircraft.